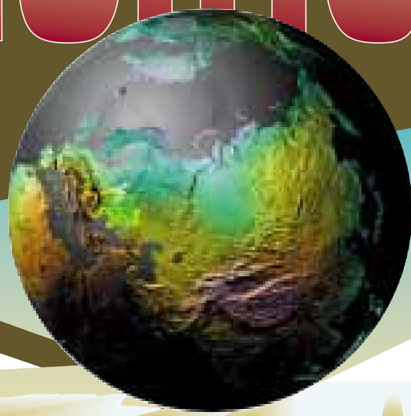
U.S. Department of Energy — Office of Fossil Energy
National Energy Technology Laboratory — Gasification Technologies Council

gasification



Worldwide Use and Acceptance

Gasification—Worldwide Use and Acceptance

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U.S. Department of Energy,
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Driving Forces for Gasification

The analysis of the driving forces for gasification is necessarily more subjective and insightful than the statistical analysis of worldwide gasification installations that follow. Nevertheless, aggregation of gasification facilities by applications, feedstocks, startup dates, and locations shows clear market trends.

Tampa Electric Company IGCC Polk Power Station

The fundamental question is, "Why are these gasification plants being built?" Understanding the information necessary to answer this question helps to identify public policy, market drivers, technical drivers, and trends that affect the degree and pace of increasing use of gasification technologies on a worldwide basis.

Clear Trends in Gasification

- *Gasification is alive and well and continues to grow.* The current annual growth in gasification is about 3,000 MW_{th} of synthesis gas, or about 7% of the total operating worldwide capacity. Planned gasification projects show this growth will likely continue.

- *The fuel of choice for new projects is low-quality petroleum pitch and petcoke.* The current trend in gasification feedstocks, which are mostly petroleum pitch and petcoke, reflects the low market value of these fuels and the increasingly stringent emission regulations associated with both air and solid waste. Fluidized bed combustion (FBC) has been promoted for these same high sulfur and heavy metals feedstocks. However, FBC produces more NO_x than gasification, cannot remove sulfur as effectively as gasification, and suffers serious solid waste problems due to the massive volume and high reactivity of FBC solid wastes.

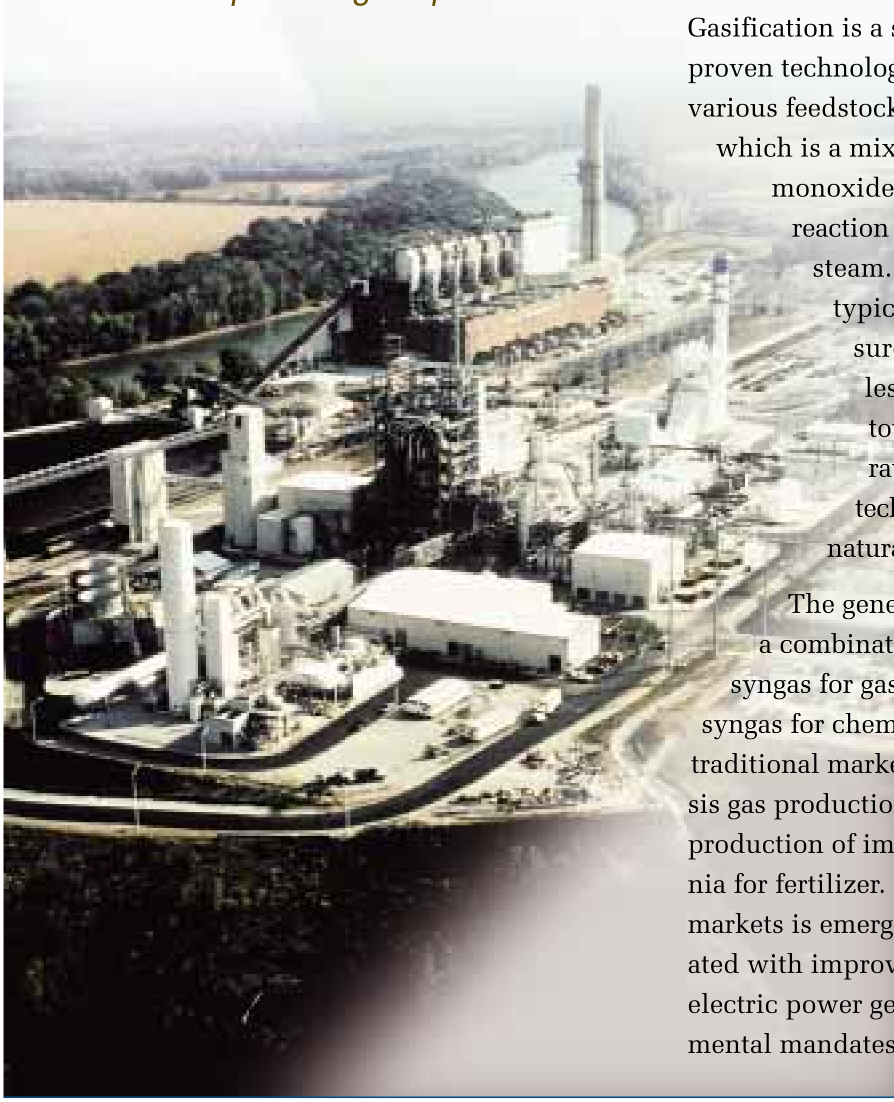
- *The current surge in gasification projects is in electric power applications in countries where electric power generation is being deregulated.* Integrated gasification combined cycle (IGCC) would have a difficult time competing with natural gas combined cycle (NGCC) in central power plant settings at current gas prices in many areas of the world. Yet gasification-based power generation represents most of the current growth in gasification. This appears to be due to polygeneration which adds flexibility that is impossible with a steam cycle, especially in a central power plant setting.

True cogeneration (over 85% efficiency with no large energy losses to barometric steam condensers) is limited in a steam cycle plant due to the low power-to-cogeneration ratio of a steam turbine. For the same cogeneration heat host, a gas turbine system can generate over five times as much electricity as a steam turbine system. This difference is significant, as electric power generation is deregulated and global climate concerns favor cost-effective efficiency improvements.

The production of synthesis gas as an intermediate product in polygeneration adds fundamental advantages over steam systems. This synthesis gas has many high-value applications in chemical plant and oil refining settings. For example, hydrogen is one of the most important chemicals in a modern oil refinery. Its use is growing at about 10% per year due to mandates for cleaner transportation fuels.

Gasification allows the polygeneration of gas turbine-based power with cogeneration steam (at high power-to-cogen heat ratio) and synthesis gas. The economy of scale associated with a high annual capacity factor and large power sales to the grid is essential to making this concept economical. The cogeneration aspect improves both economics and efficiencies relative to central power plants. Moreover, the synthesis gas product increases both revenue options and annual load factors that are impossible with straight power generation alone. This polygeneration concept is only possible if electricity can be sold to the grid at a fair price.

Wabash River Coal Gasification Repowering Project



INTRODUCTION

Gasification is a simple and commercially well-proven technology. It involves the conversion of various feedstocks to clean synthesis gas (syngas) which is a mixture of hydrogen (H_2)and carbon monoxide (CO). Gasification usually entails reaction of the feedstock with oxygen and steam. This reaction or conversion is typically at high temperature and pressure under reducing conditions, as less than half the oxygen required for total combustion is added. The hot raw syngas is cooled and purified by technologies that are commonly used in natural gas purification and oil refining.

The generated syngas is then used in one or a combination of many product applications—syngas for gaseous fuels, syngas for liquid fuels, syngas for chemicals, and syngas for power. The traditional market for gasification has been synthesis gas production as an intermediate step in the production of important chemicals, such as ammonia for fertilizer. Application of gasification in other markets is emerging due to market changes associated with improved gas turbines, deregulation of electric power generation, and stringent environmental mandates.

A database of gasification projects is a powerful tool that can be used to assess the role of gasification technology in current world energy markets and its potential to contribute to meeting future energy demand cleanly and efficiently. SFA Pacific, Inc. has developed such a database of commercial gasification facilities to illustrate, characterize, and enumerate the worldwide gasification industry on a consistent basis. This database is then used to analyze the driving forces behind the development of these facilities. Prior to this time, there did not exist a credible, complete, worldwide survey of gasification installations in the public domain.

Highlights of the project, "Worldwide Gasification Industry Report," being prepared by SFA Pacific, Inc. for the U.S. Department of Energy (DOE) and the Gasification Technologies Council (GTC) follow. Copies of the final report and database package will be available from DOE when they are completed.

Database Methodology

The development of the gasification database involved collection and organization of information on specific facilities where gasification technology is employed. The database was compiled based on information on gasification technologies and projects available to SFA Pacific from nonproprietary public reference sources, including the following:

- Reference material presented at GTC-sponsored conferences on gasification
- Reference material and installation lists from licensors of gasification technology
- Reference material and installation lists from contractors and technology suppliers involved in the engineering and construction of gasification facilities
- Reference material authored by SFA Pacific including:
  - "Coal Gasification Guidebook: Status, Applications, and Technology" EPRI TR-102034 (December 1993)
  - Multisponsored client studies on hydrogen, synthesis gas, refiner-based power, and upgrading petroleum residues
  - Feature articles in *The SFA Quarterly Report*

Database Structure

The database was developed in Microsoft Access, which is a relational database management system. It has been structured for easy use and updating, and allows sorting and searching on various aspects of gasification projects. The principal structure of the database involves listings of projects according to gasification technology licensor. Data entry forms were developed and filled in as completely as possible for each commercial gasification facility in the world, indicating the following key information:

- Project ownership
- Gasification technology used
- Year gasifier(s) placed in service
- Operational status
- Project location (country and region)
- Project type (pilot or commercial scale)
- Size (MW_{th} synthesis gas capacity)
- Gasification application
- Feedstocks and products

There are over 100 input fields available for each plant's data sheet, including references for data sources. As much information as possible is reported for each specific commercial gasification project. However, on some plants, only a few of the most essential inputs are available. Contact information, such as name, e-mail address, and phone number of key equipment vendors, contractors, and plant owners are also included when available.

Gasification plant capacity is often reported in units of the volumetric output of synthesis gas (i.e., normal cubic meters or standard cubic feet per day). However, the volumetric measure is often difficult to comprehend. Therefore, SFA Pacific converted all gasification input and output capacities to MW_{th} (note: 1 MW_{th} = 3,413,000 Btu/hr). The use of MW_{th} synthesis gas output is quite useful because many of the newer and larger gasification facilities co-produce electric power, cogeneration steam, and synthesis gas. An equivalent MW of electric power capacity is also calculated based on the power equivalent if all the gasification output were used in a modern combined cycle.

Data Verification

The focus of the database is on "real" projects—those that are currently operating, under construction, or in the advanced engineering stage. With the cooperation of the major gasification licensors and the Gasification Technologies Council, data sheets were completed for each gasification facility. These data sheets were then reviewed by the specific gasification licensors to verify the accuracy of the data collected. Information on some gasification projects could not be provided by the technology licensors due to confidentiality agreements with project owners. These units are usually gasifiers used by chemical companies for highly competitive synthesis gas applications. In these instances, SFA Pacific estimated essential project data to assure that their capacities are represented in the database. The technology licensors were shown these assumptions and estimates.

Pilot plants and shut down and/or dismantled gasification units are included in the database for completeness. However, data for these projects are not included in the analysis of the gasification industry due to the focus on real commercial-scale units. Large commercial-scale demonstrations, such as the U.S. Clean Coal Technology IGCC plants, are included as real commercial units. Proposed gasification plants that are actively being planned are included to illustrate market trends, but are clearly distinguished from real projects that are (or were at one time) either operating or are being built.

Gasification Database Results

The complete database has records for 329 gasification projects, representing a total of 754 gasifiers (including many small pilot plants and shutdown/dismantled units). To assess the role of gasification technology in current world energy markets it is more useful to review only data for the commercial-scale real and actively planned gasification projects.

The gasification database contains records for 161 real and planned commercial-scale gasification projects, representing a total of 414 gasifiers with a combined rating of 446 million Nm3/d of synthesis gas or 60,882 MW_{th} of synthesis gas output. Conversion of all of this synthesis gas to IGCC electricity equates to 33,284 MWe of power equivalent. Of the total worldwide commercial-scale gasification capacity, active-real projects (those currently operating or under construction) account for 128 plants with a total of 366 gasifiers and a combined rating of 42,726 MW_{th} of synthesis gas capacity. Actively planned projects account for 33 plants with 48 gasifiers rated at 18,156 MW_{th} of synthesis gas capacity. These are generally large units being considered for electric power generation. The top 30 commercial gasification projects are listed in Table 1 according to MW_{th} of synthesis gas output. This table reflects the diversity in location of gasification projects, as well as the different technologies employed, feeds consumed, and products produced.

Top 30 Commercial Gasification Projects Listed According to Size

Gasification Plant Owner	Location	Gasification Technology	MW_{TH} SG Output	Startup Year	Feed/Product
Sasol-II	South Africa	Lurgi Dry Ash	4,130	1977	Subbit. coal/FT liquids
Sasol-III	South Africa	Lurgi Dry Ash	4,130	1982	Subbit. coal/FT liquids
Repsol/Iberdrola	Spain	Texaco	1,654	2004[a]	Vac. residue/Electricity
Dakota Gasification Co.	United States	Lurgi Dry Ash	1,545	1984	Lignite & Refinery residue/SNG
SARLUX srl	Italy	Texaco	1,067	2000[b]	Visbreaker residue/Electricity & H2
Shell MDS Sdn. Bhd.	Malaysia	Shell	1,032	1993	Natural gas/Mid-distillates
Linde AG	Germany	Shell	984	1997	Visbreaker residue/H2 & Methanol
ISAB Energy	Italy	Texaco	982	1999[b]	ROSE asphalt/Electricity & H2
Sasol-I	South Africa	Lurgi Dry Ash	911	1955	Subbit. coal/FT liquids
Total France/EdF/Texaco	France	Texaco	895	2003[a]	Fuel oil/Electricity & H2
Unspecified owner	United States	Texaco	656	1979	Natural gas/Methanol & CO
Shell Nederland Raffinaderij BV	Netherlands	Shell	637	1997	Visbreaker residue/H2 & Electricity
SUV/EGT	Czech Republic	Lurgi Dry Ash	636	1996	Coal/Electricity & Steam
Chinese Petroleum Corp.	Taiwan	Texaco	621	1984	Bitumen/H2 & CO
Hydro Agri Brunsbüttel	Germany	Shell	615	1978	Hvy vac. residue/Ammonia
Public Service of Indiana	United States	Destec	591	1995	Bit. coal/Electricity
VEBA Chemie AG	Germany	Shell	588	1973	Vac. residue/Ammonia & Methanol
Elcogas SA	Spain	PRENFLO	588	1997	Coal & petcoke/Electricity
Motiva Enterprises LLC	United States	Texaco	558	1999[b]	Fluid petcoke/Electricity & Steam
API Raffineria di Ancona S.p.A.	Italy	Texaco	496	1999[b]	Visbreaker residue/Electricity
Chemopetrol a.s.	Czech Republic	Shell	492	1971	Vac. residue/Methanol & Ammonia
Demkolec BV	Netherlands	Shell	466	1994	Bit. coal/Electricity
Tampa Electric Co.	United States	Texaco	455	1996	Coal/Electricity
Ultrafertil S.A.	Brazil	Shell	451	1979	Asphalt residue/Ammonia
Shanghai Pacific Chemical Corp.	China	Texaco	439	1995	Anthracite coal/Methanol & Town gas
Exxon USA Inc.	United States	Texaco	436	2000[b]	Petcoke/Electricity & Syngas
Shanghai Pacific Chemical Corp.	China	IGT U-GAS	410	1994	Bit. Coal/Fuel gas & Town gas
Gujarat National Fertilizer Co.	India	Texaco	405	1982	Ref. residue/Ammonia & Methanol
Esso Singapore Pty. Ltd.	Singapore	Texaco	364	2000[b]	Residual oil/Electricity & H
Quimigal Adubos	Portugal	Shell	328	1984	Vac. residue/Ammonia

[a] Plant is currently in advanced engineering. [b] Plant is currently under construction.

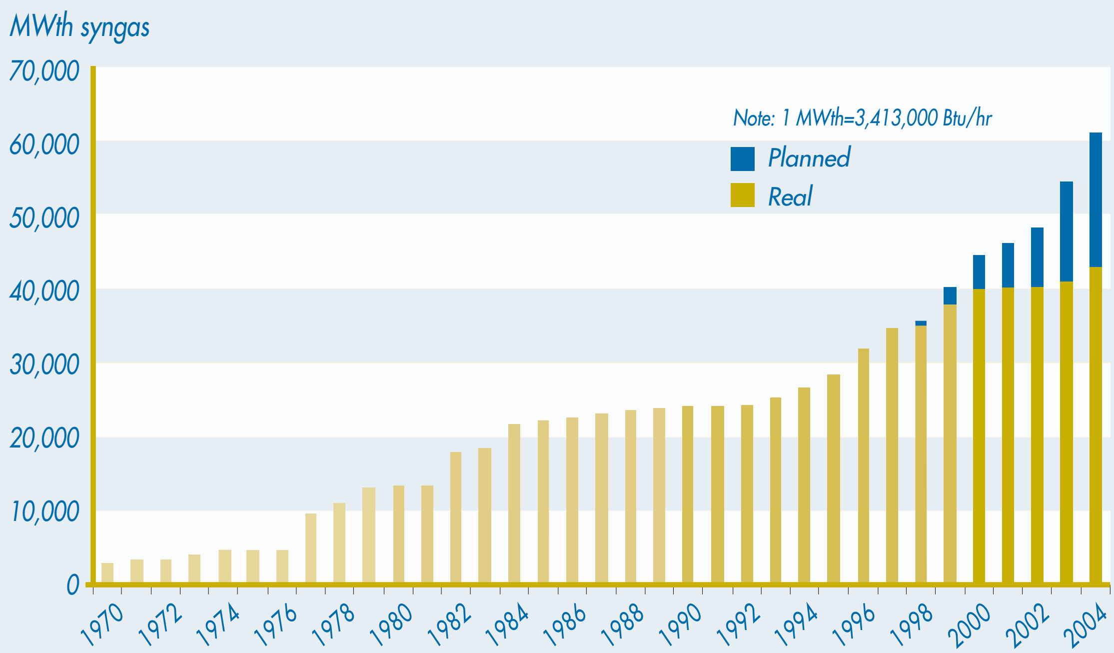
Worldwide Gasification Capacity and Growth

The cumulative worldwide gasification capacity of 60,883 MW_{th} of synthesis gas in Figure 1 shows a clear and sustained growth in gasification. In the past, traditional gasification plants for synthesis gas chemical applications were quite small, typically only 200-300 MW_{th} of synthesis gas output. The startup of Sasol-II in 1977 and Sasol-III in 1982 resulted in large increases in worldwide gasification capacity in those years due to the magnitude of these gasification plants. For example, Sasol-II and Sasol-III each generate 4,130 MW_{th} of synthesis gas output. The order of magnitude of the large size of the Sasol projects reflects the production of synthetic fuels compared to traditional smaller synthesis gas chemicals projects.

The current growth in gasification is mostly in electric power generation. As with fuels, electric power generation markets are orders of magnitude larger than the chemicals market. Deregulation enables electric power to be generated by IGCC in the traditional electric utility setting or in the industrial setting. IGCC projects have generally been limited to a handful of commercial-scale IGCC demonstration plants. Much of the current surge in gasification capacity is in industrial polygeneration, which is defined as co-production of cogeneration steam and power, plus synthesis gas for hydrogen or chemicals.

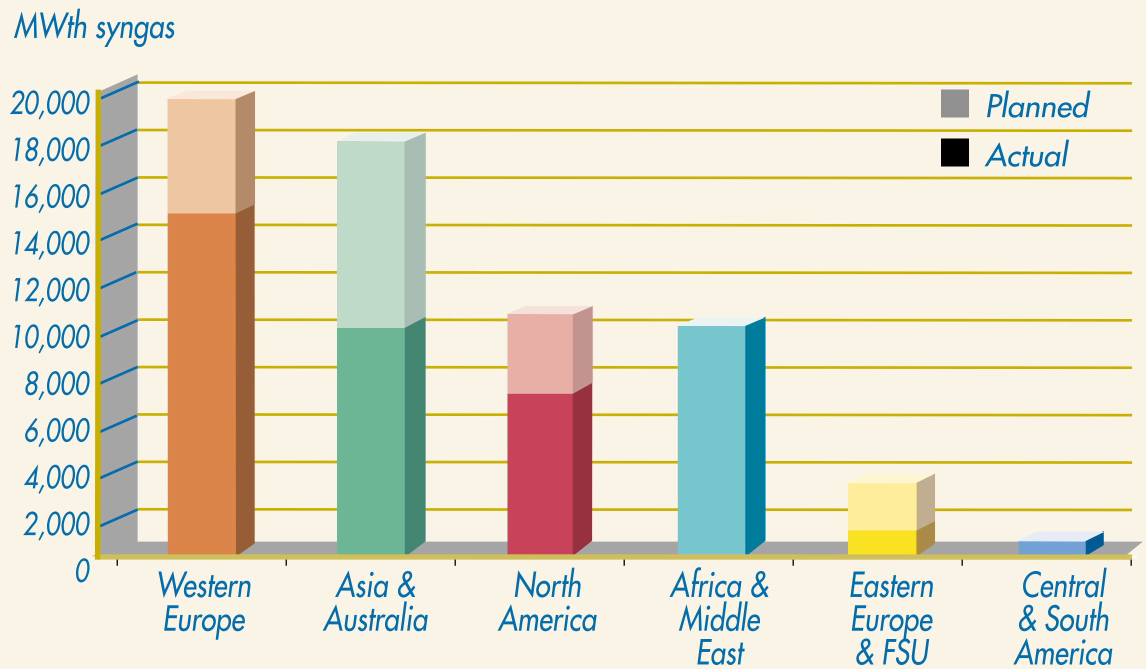
Figure 1

Cumulative Worldwide Gasification Capacity and Growth



Industrial polygeneration also enhances the economic competitiveness of gasification for synthesis gas chemicals application. The extra gasification capacity added to generate power for sale to the grid reduces the unit cost of synthesis gas, because gasification is capital intensive. The typically large size of power generation projects adds significant economies of scale, thereby reducing the unit costs of synthesis gas.

Figure 2
Gasification by Geographic Region



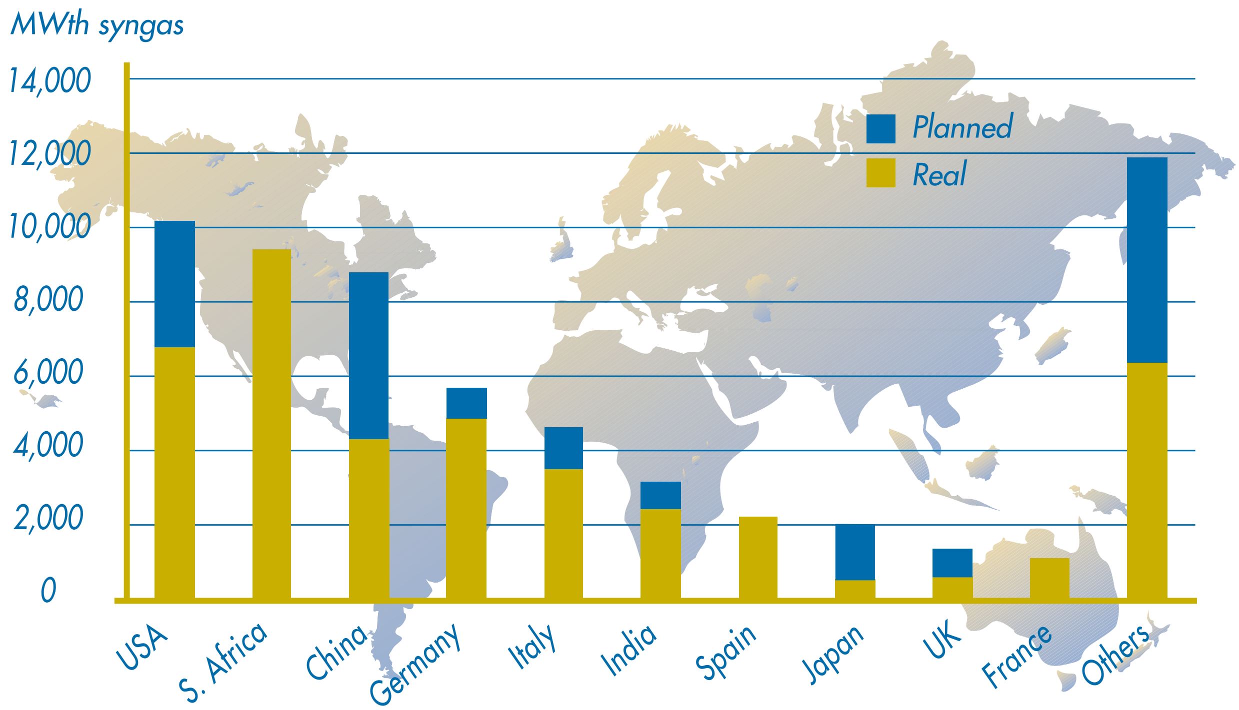
Gasification by Location

The distribution of gasification project locations is shown by geographic region and by country in Figures 2 and 3, respectively. Western Europe is the leading region for gasification based on MW_{th} of synthesis gas output of real and planned projects. Most of the newer European gasification projects are large oil refinery polygeneration projects that involve major upgrades of refineries to reduce production of heavy fuel oil. In the past, there were strong markets for low quality (high sulfur and metal) heavy fuel oil as power plant fuel, especially in Southern Europe. Today, deregulation of power generation throughout Europe and new stringent emission regulations in Southern Europe are causing major changes in both European power generation and oil refinery production.

Western European oil refiners are making major investments to eliminate or greatly reduce residual fuel oil production. Gasification is being effectively used to convert the low-quality pitch residues from heavy oil processing (usually hydrotreating, hydrocracking, vis-breaking, or solvent deasphalting). The resulting clean synthesis gas is being used for polygeneration of electric power, cogeneration steam, and hydrogen (often required by these heavy oil upgraders). The scale of electric power generation is usually large, thanks to sales to the grid. Italy has price supports for this clean, high-efficiency electricity to encourage these types of oil refinery upgrades. There are also major projects in the Netherlands, France, and Spain, with no subsidies.

Asia and Australia comprise the second largest region for gasification based on MW_{th} of synthesis gas output of real and planned projects. China is the dominant gasification market country in this region, based on total number of projects and MW_{th} of synthesis gas output. However, gasification in China is currently limited to chemical synthesis gas applications due to the highly regulated energy markets,

Figure 3
Gasification by Country



which limit polygeneration electric power sales to the grid. Japan's current growth in gasification is in refinery power generation. This situation is due to recent changes in Japan's energy policy that encourage electric utilities to solicit lower-cost power from private industry.

The entire Africa and Middle East region is dominated by Sasol's three large gasification plants. With lower world oil prices, better trade relations, and reduced subsidies in this region in recent years, there are no planned additions of Sasol-type coal gasification facilities in the entire region.

North America is the only other region of the world where there is extensive use of gasification. The United States is the dominant market in this region. Like Germany, there are smaller, traditional gasification plants for synthesis gas chemicals.

There are also some significant nontraditional gasification projects in the United States, such as the large Dakota Gasification synthetic natural gas via coal gasification plant in North Dakota, which started up in 1984.

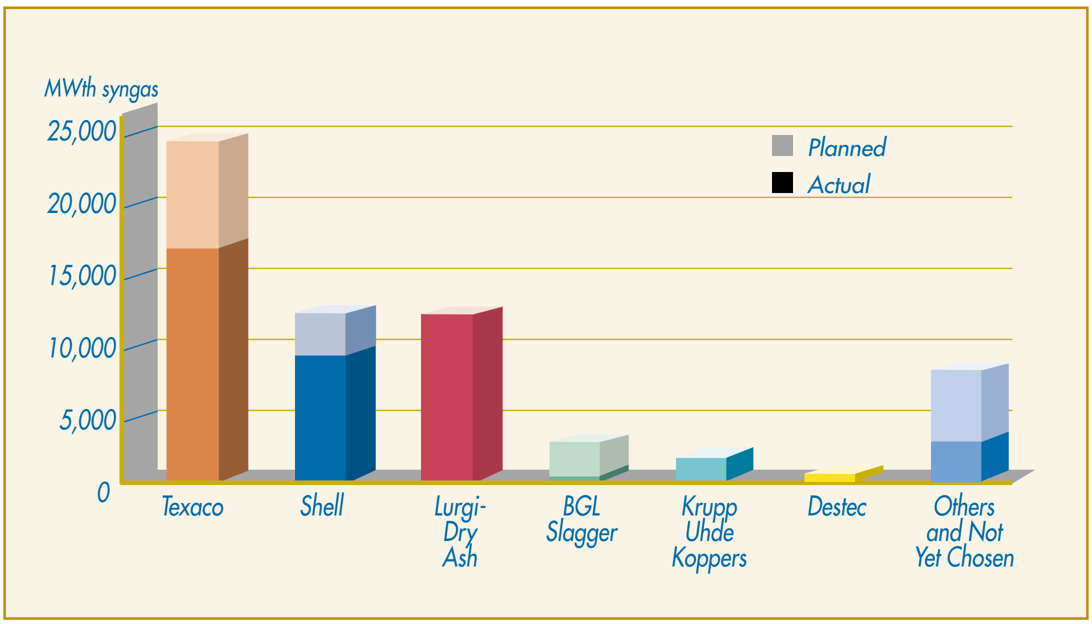
Most of the newer U.S. gasification activity is for large electric power generation projects, e.g., about half for IGCC demonstration and half for oil refinery polygeneration. The refinery gasification projects have no subsidies and appear to be driven by utilization of low-value/low-quality petroleum coke and the superior environmental performance of gasification. The high sulfur and heavy metals content of this fuel give gasification a major advantage over direct combustion of the petcoke.

Gasification by Technology

The commercially well-proven Texaco, Shell, and Lurgi (Dry Ash) gasification technologies represent a major portion of the total worldwide gasification capacity, as illustrated in Figure 4. Texaco is the leading licensor of gasification technology based on total capacity, representing nearly 40% of the real capacity, with 63 projects accounting for 16,483 MWth of synthesis gas output. The Lurgi Dry Ash and Shell gasification technologies represent nearly 28% and 21% of real capacity, respectively, with seven projects generating 11,842 MW_{th} and 28 projects generating 8,967 MW_{th}, respectively. Texaco and Shell continue to add new projects, with 7,559 MW_{th} and 3,000 MW_{th}, respectively, of synthesis gas output planned in new projects. There appears to be little interest in new Lurgi Dry Ash gasifiers, which is likely due to the feedstock limitation, large steam addition, and extensive waste liquids clean-up requirements of Lurgi Dry Ash gasifiers. These limitations do not exist for the Texaco and Shell technologies. The surge in refinery polygeneration projects also helps the Texaco and Shell technologies, as both are well known in this industry and are quite experienced with processing low-value refinery feedstocks. Texaco has the added advantage of more experience with petcoke.

Figure 4

Gasification by Technology

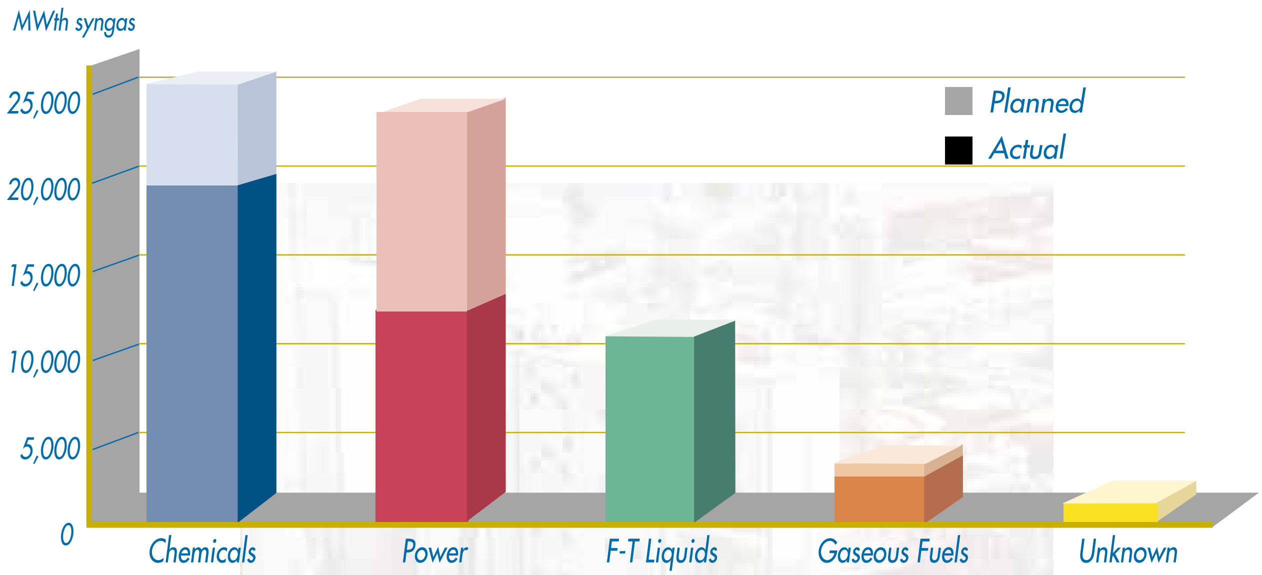


Gasification by Application

Synthesis gas for chemicals continues to be the dominant application or product of gasification, as shown in Figure 5. This application includes 89 real projects accounting for 18,361 MW_{th} of synthesis gas output. Power generation is gaining quickly, and represents most of the recent and planned capacity additions, with 20 new projects planned to generate 10,758 MW_{th} of synthesis gas output. Much of this growth is in gasification-based power generation in oil refinery polygeneration.

Figure 5

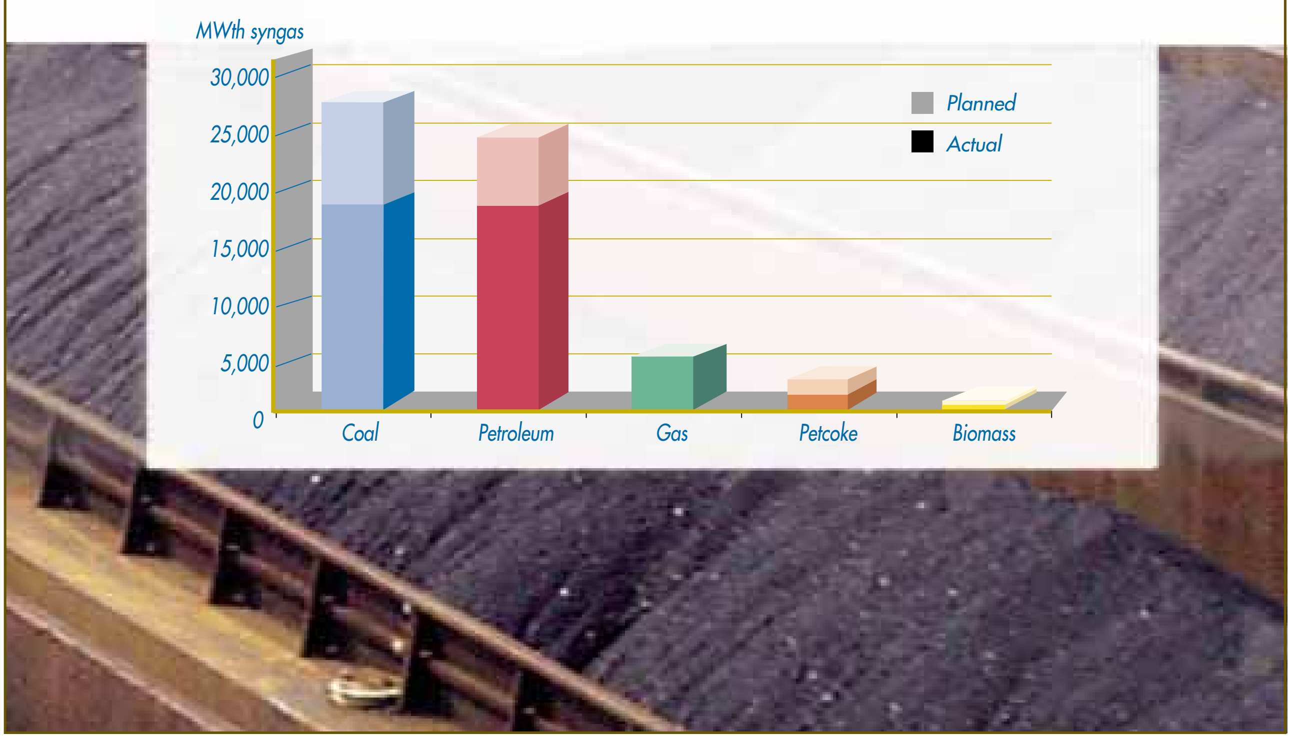
GASIFICATION BY APPLICATION



Liquid Phase Methanol Demonstration
Kingsport, Tennessee

Figure 6

GASIFICATION BY PRIMARY FEEDSTOCK



Gasification by Primary Feedstocks

Coal and petroleum (mainly heavy residues) are the dominant feedstocks for gasification projects, as shown in Figure 6. Coal is limited to just 29 real projects, accounting for 17,929 MW_{th} of synthesis gas output. The Sasol, Dakota Gasification, and a few IGCC demonstration projects represent most of this coal capacity. The remaining coal capacity is generally a few small synthesis gas chemical projects in China, India, Africa, and the United States. There are 56 real projects based on petroleum feedstocks (including fuel oil, refinery residue, naphtha, etc.) generating 17,789 MW_{th} of synthesis gas output. In addition, there are five real projects based on petcoke—another petroleum feedstock—generating 1,393 MW_{th} of synthesis gas output. Low-quality residual oil and petcoke currently have price advantages over coal.

Growing environmental concerns are also becoming drivers for increased use of gasification. The air emissions of gasification can be as low as for those of a natural gas-based system. The largest advantage of gasification over both direct combustion and advanced pressurized FBC (PFBC) concepts is in the area of solid wastes. Most gasifiers produce elemental sulfur and vitrified slag. The market potential of these streams is significantly better than that of the solid waste produced by FBC due to the much larger mass, volume, and reactivity of FBC spent sorbent. This issue is becoming important due to the increased interest in low-quality petroleum pitch/petcoke utilization, and because of mandates for more recycling and less solid waste disposal. There is a clear environmental trend which favors producing benign vitrified slag.

Future of Gasification

The future of gasification is clearly impacted by changes in government policy. Continuing convergence of oil, gas, and electric power marketing with deregulation improves the potential for gasification. Increasing interest in improved energy efficiency, reduced emissions, and increased recycle of wastes also helps gasification.

Electric power generation is the key market for gasification. Demand for electricity is growing at a rate twice that of other end-use energy forms, such as natural gas and transportation fuels. Gasification will become more competitive in the long term as the current dominance of NGCC will lessen as natural gas prices increase. Gasification enables all feedstocks to meet the same emission levels as NGCC. Current pitch and petcoke gasification is a bridge to long-term coal gasification.

Technical trends, which help gasification, include improving gas turbines and poly-generation. Each increase in combined-cycle efficiency directly reduces the size and cost of the gasification facility required to fire that combined cycle. Advanced intercooled, recuperated, reheat gas turbines have the potential of power-to-cogeneration heat ratio that is an order of magnitude higher than that possible with steam turbines. Polygeneration is unique to gasification and, with deregulation, this concept will develop. Gasification has strategic emission, efficiency, and economic flexibility for the future.

For additional information log onto these websites or contact one of the people listed below.

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